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(54) **BELT CONVEYOR AND
ELECTROMAGNETIC DRIVE**

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See application file for complete search history.

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B65G 47/10 (2006.01)
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(2013.01)

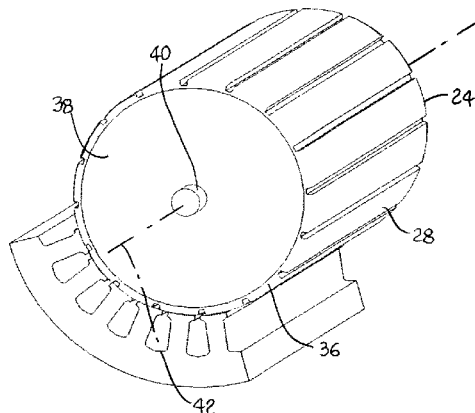
(58) **Field of Classification Search**

CPC H02K 7/14

(57) **ABSTRACT**

A belt conveyor having an electromagnetic drive comprising a rotor and a stator sealed in separate nonmagnetic and non-conductive housings. The rotor is mounted to a drive shaft. A drive drum or drive sprockets supported on the shaft have peripheral drive surfaces that engage a conveyor belt. The rotor is coaxial with the peripheral drive surface—either sealed within the drum or sprockets or housed on the shaft axially spaced from the drive surface. The rotor may include conductive rotor bars or permanent magnets. The stator is spaced apart from the rotor across a narrow gap and produces a traveling magnetic flux wave across the gap that causes the rotor and the peripheral drive surface to rotate and drive the conveyor belt.

20 Claims, 11 Drawing Sheets



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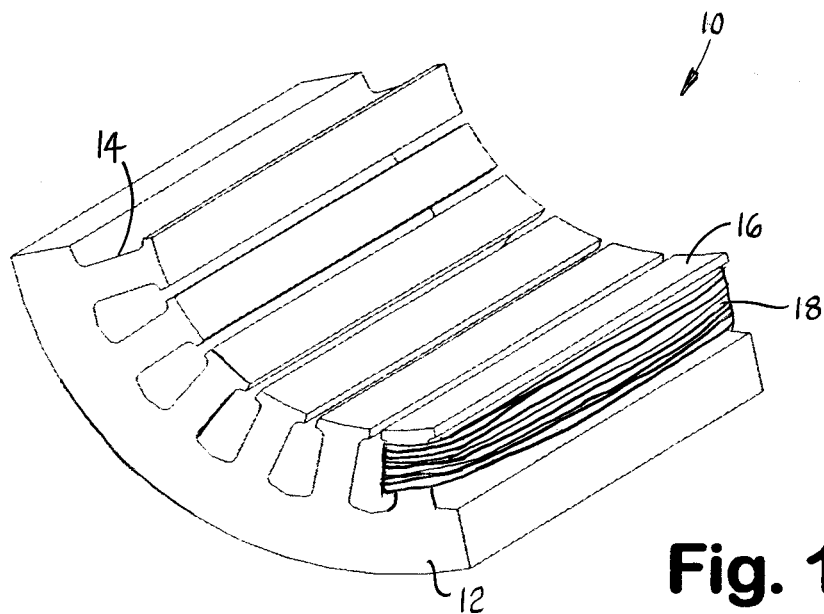


Fig. 1a

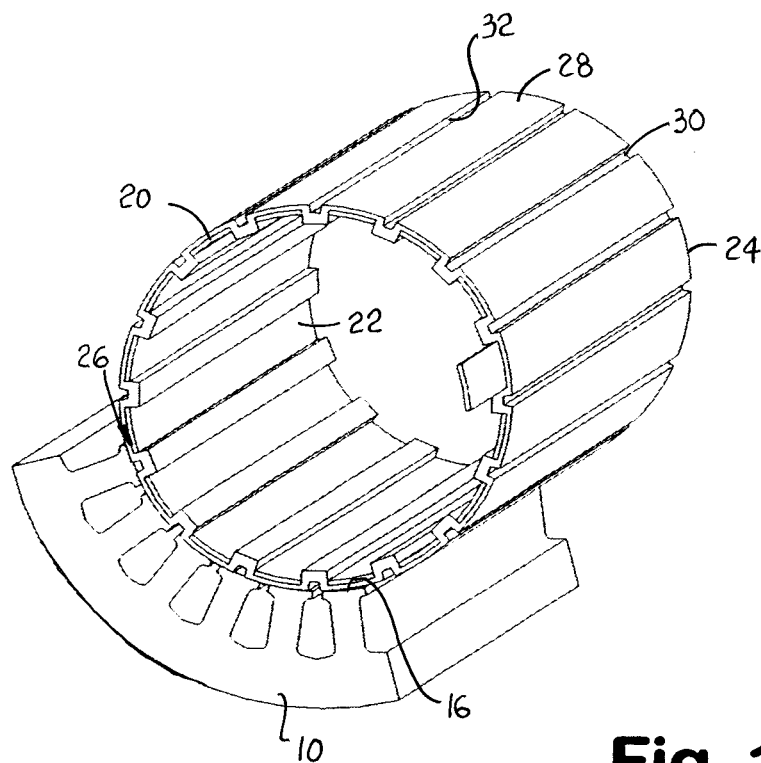


Fig. 1b

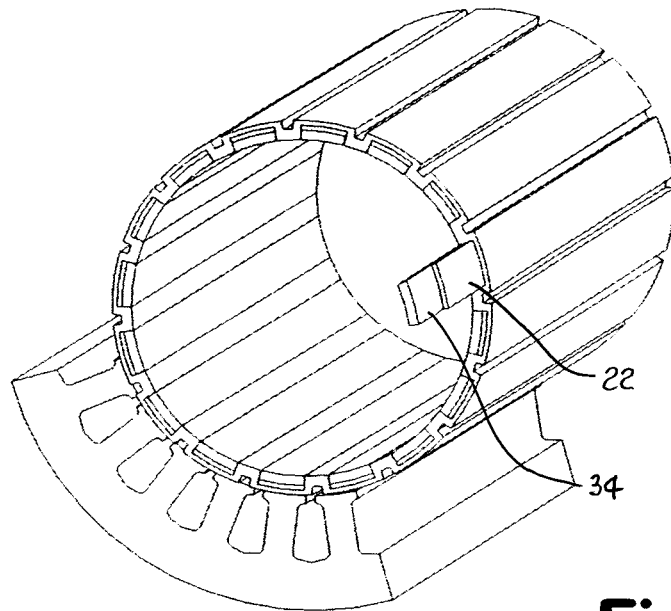


Fig. 1c

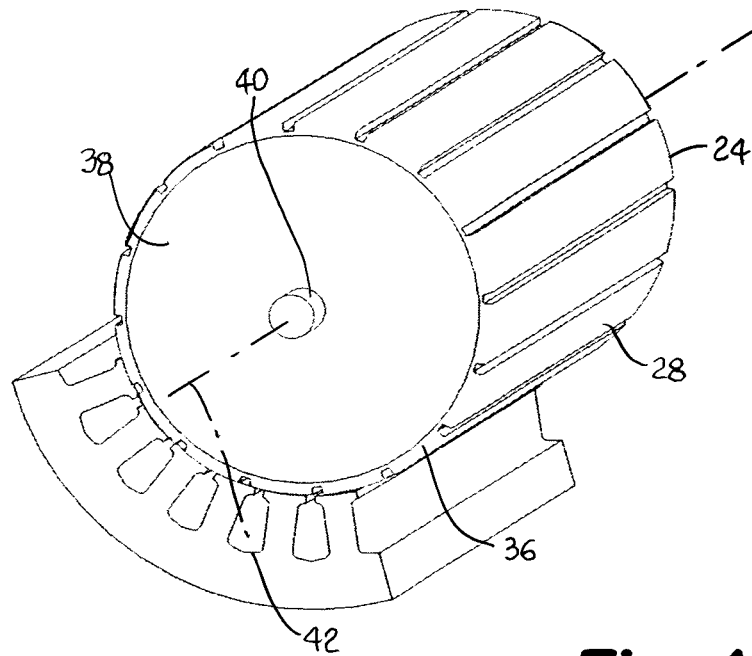


Fig. 1d

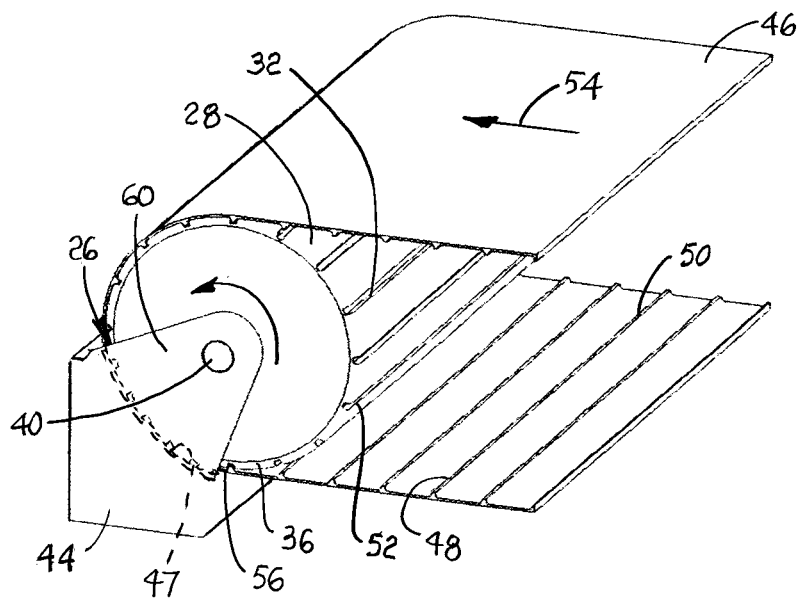


Fig. 2

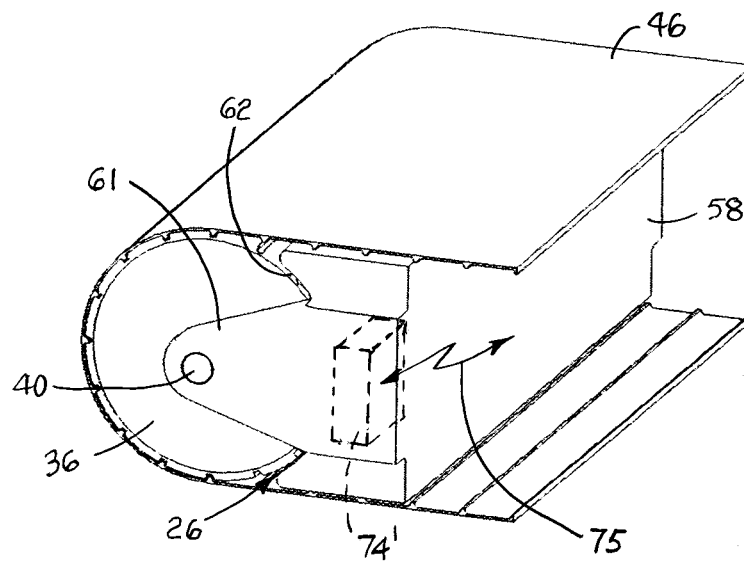
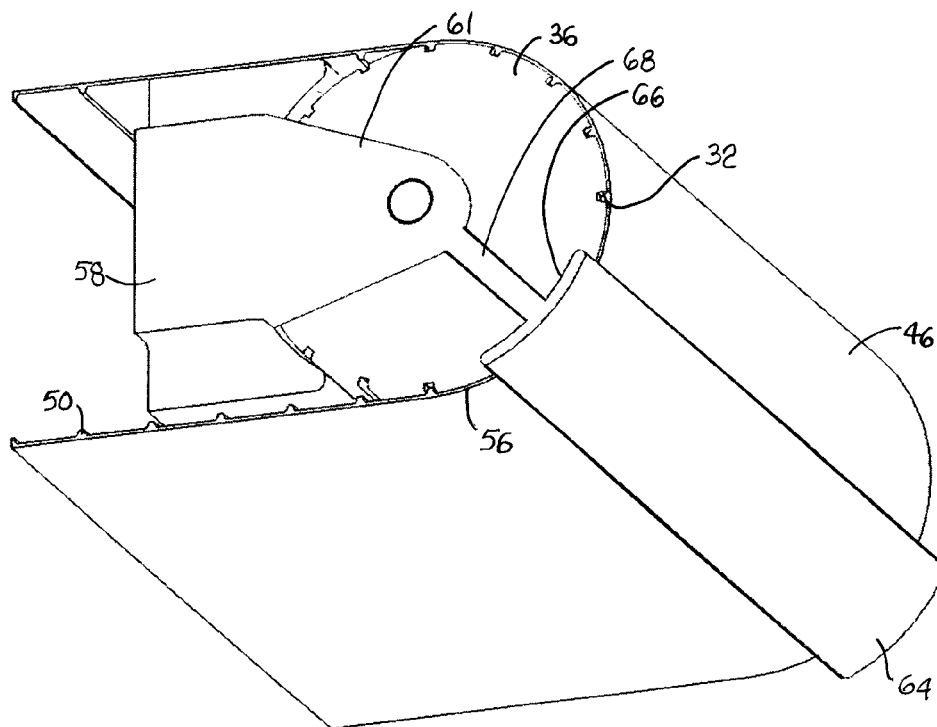


Fig. 3

**Fig. 4**

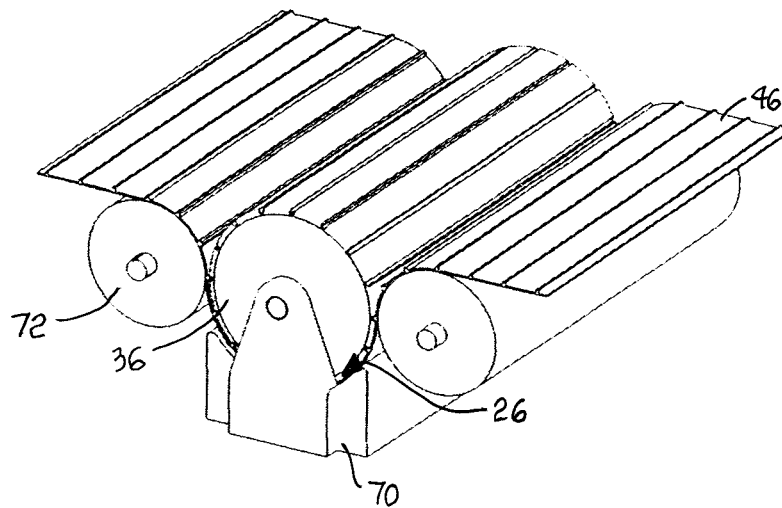


Fig. 5

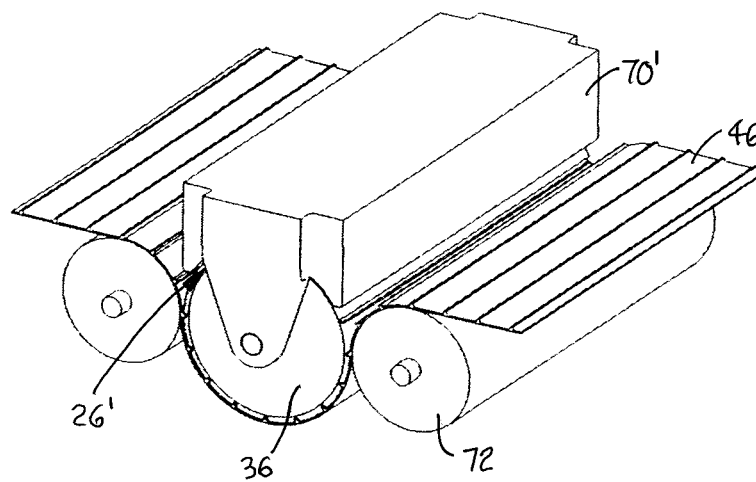


Fig. 6

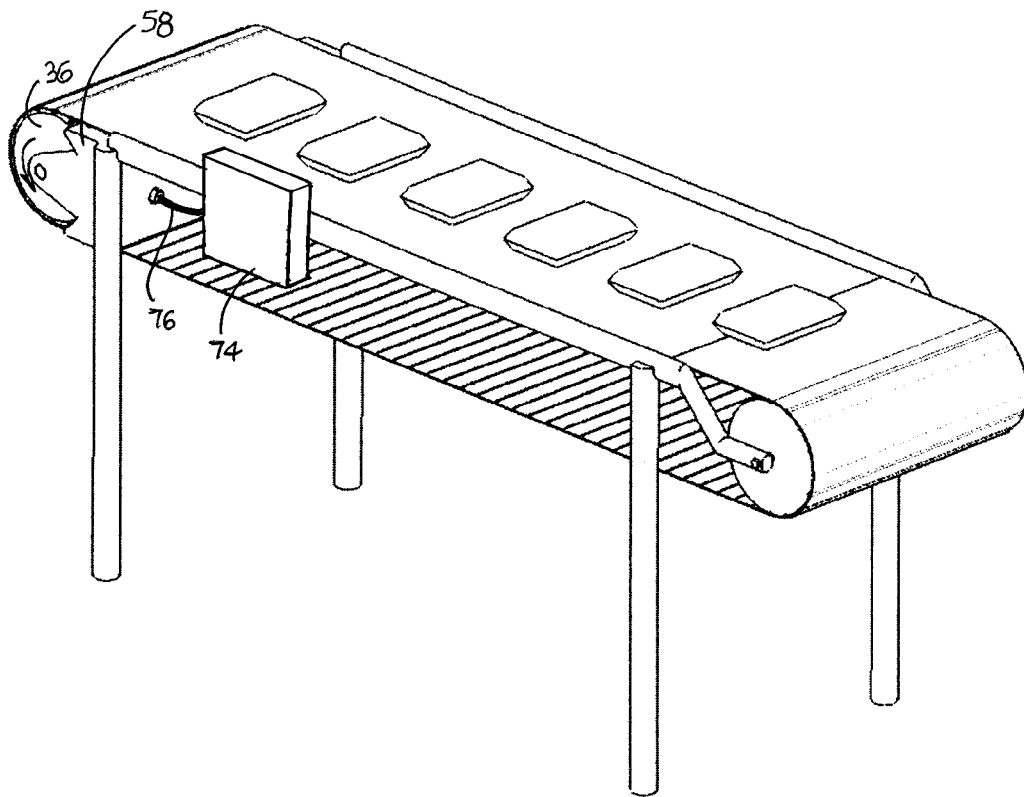


Fig. 7

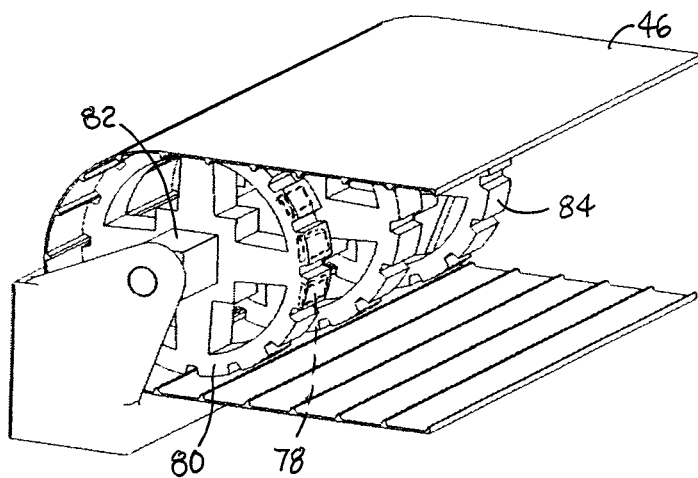


Fig. 8a

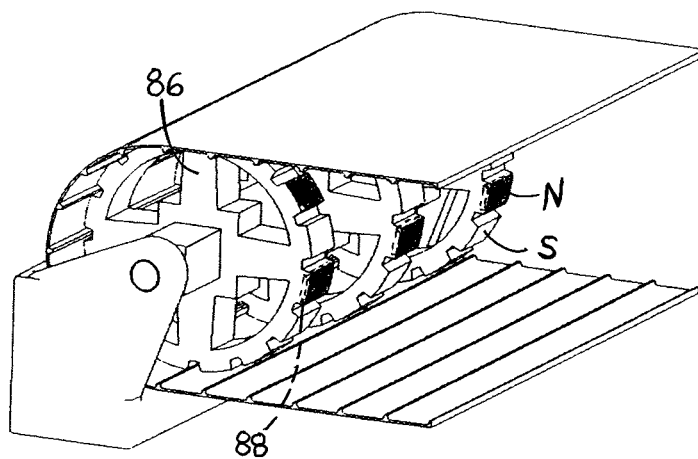


Fig. 8b

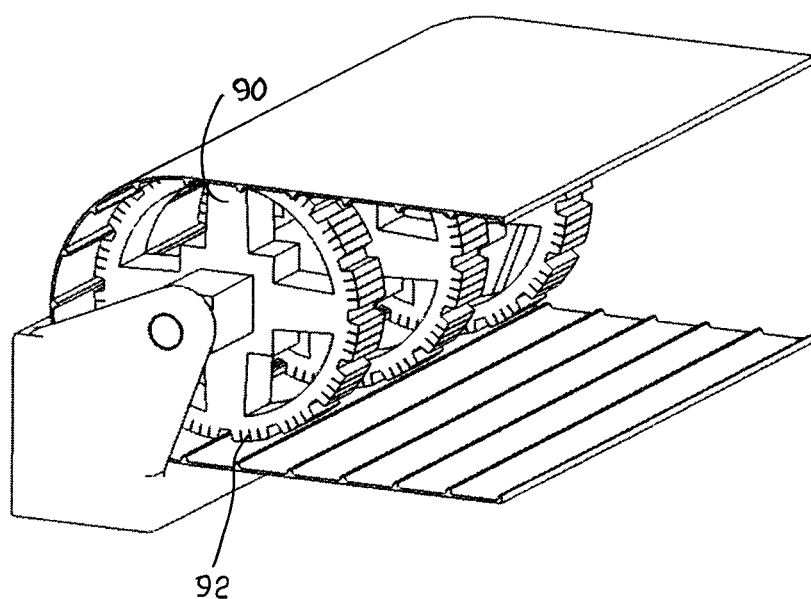


Fig. 8c

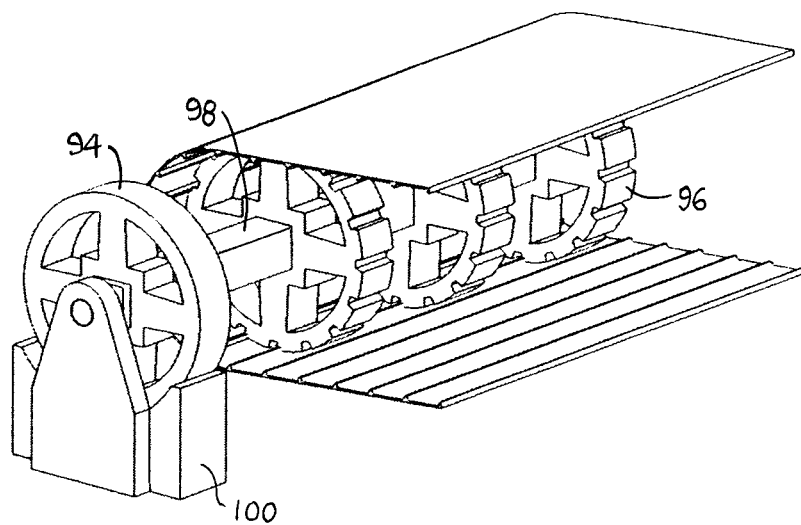


Fig. 9a

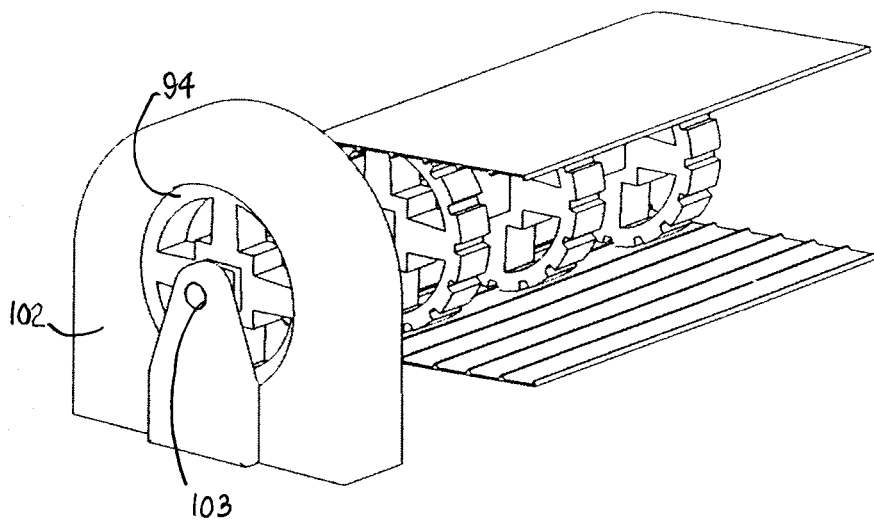


Fig. 9b

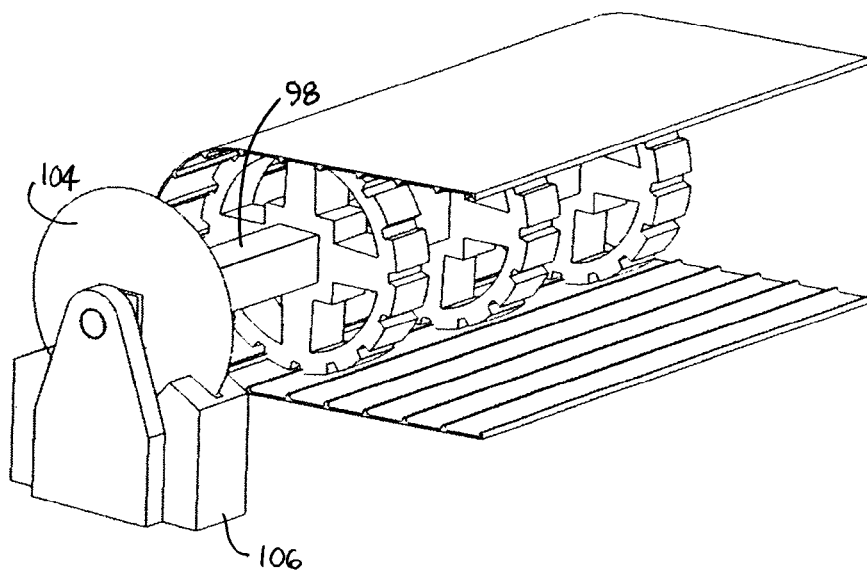


Fig. 9c

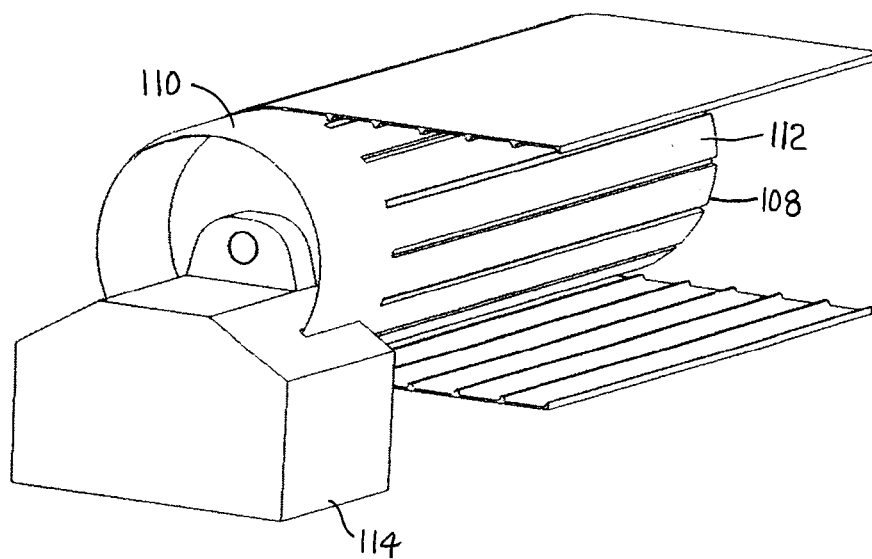


Fig. 9d

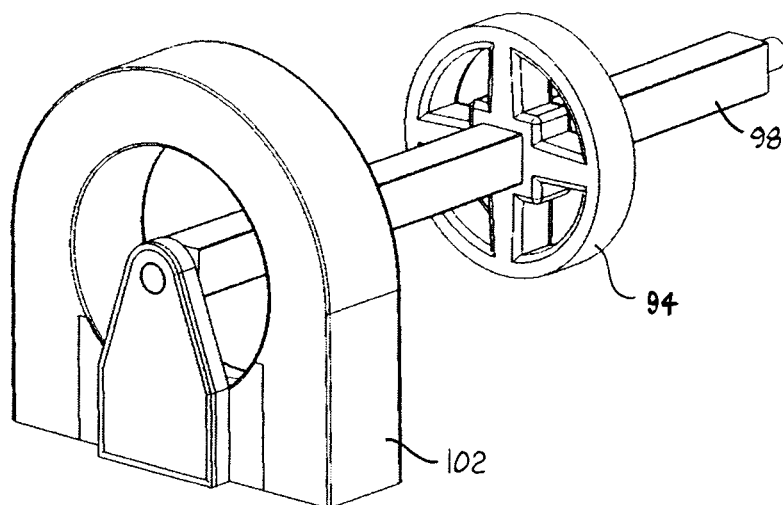


Fig. 9e

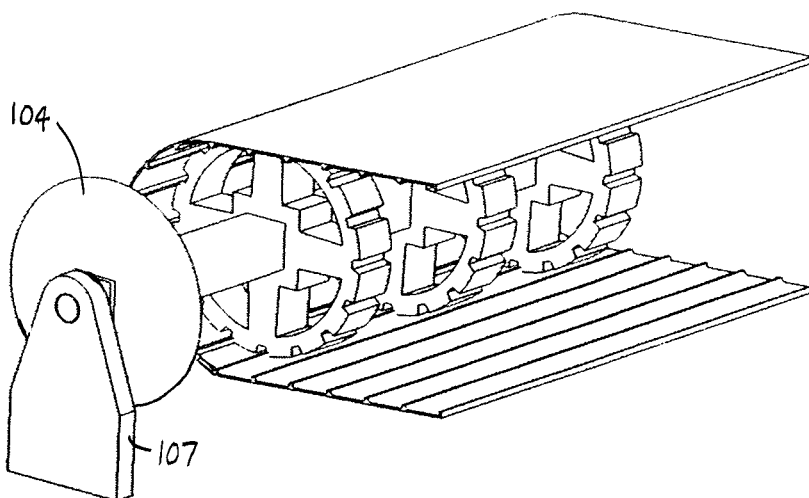


Fig. 9f

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BELT CONVEYOR AND ELECTROMAGNETIC DRIVE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of co-pending U.S. patent application Ser. No. 14/048,092, filed Oct. 8, 2013, which claims the benefit of U.S. Provisional Patent Application No. 61/715,383, filed Oct. 18, 2012. The disclosures of both those applications are incorporated into this application by reference.

BACKGROUND

The invention relates generally to power-driven conveyors and more particularly to belt conveyors driven by separately housed stators and rotors.

Conveyor belts are conventionally driven by sprockets, drums, or pulleys mounted on a drive shaft rotated by an electric motor via a reduction gear, a sprocket-chain system, or a belt-pulley system. These standard components present many hiding places for debris and other contaminants. In the food processing industry, the harboring of contaminants and bacteria is problematic. Furthermore, reduction gears wear out and require lubrication.

SUMMARY

A conveyor-belt drive embodying features of the invention comprises a drive element rotatable about an axis of rotation and a stator. The drive element has a rotor and a peripheral drive surface adapted to engage a conveyor belt. The stator is separated from the rotor across a gap that extends partway around the rotor and that receives the conveyor belt between the drive element and the stator. The stator produces a traveling magnetic flux wave across the gap that interacts with the rotor to cause the rotor to rotate the drive element and drive the conveyor belt engaged by the peripheral drive surface.

Another version of a conveyor-belt drive comprises a drive element that is rotatable about an axis of rotation and a stator. The drive element has a rotor and a peripheral drive surface that includes drive faces circumferentially spaced at a regular pitch for positively engaging drive-receiving surfaces on a conveyor belt. The stator is separated from the rotor across a gap that extends partway around the rotor. The stator produces a traveling magnetic flux wave across the gap that interacts with the rotor to cause the rotor to rotate the drive element and drive the conveyor belt engaged by the drive faces on the peripheral drive surface.

BRIEF DESCRIPTION OF THE DRAWINGS

These aspects and features of the invention, as well as its advantages, are described in more detail in the following description, appended claims, and accompanying drawings, in which:

FIG. 1a is an isometric view of a stator usable in a conveyor-belt drive embodying features of the invention;

FIG. 1b is an isometric view of one version of a drive system using a stator as in FIG. 1a and a conductive-bar rotor in a drive drum;

FIG. 1c is an isometric view of an alternative version of the drive system of FIG. 1b with steel reaction bars backing the rotor bars in the drive drum;

FIG. 1d is an isometric view of the drive system of FIG. 1b sealed with end caps;

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FIG. 2 is an isometric view of a conveyor system using a stator as in FIG. 1a sealed in a housing under the drum and pressing against the outer surface of a conveyor belt;

FIG. 3 is an isometric view of a conveyor system as in FIG. 2, but with the stator sealed in a housing behind the drum;

FIG. 4 is an isometric view of a conveyor system as in FIG. 3 with a dedicated position limiter;

FIG. 5 is an isometric view of a center-driven conveyor with a stator as in FIG. 1a mounted in a housing below the belt returnway;

FIG. 6 is an isometric view of a conveyor as in FIG. 5 with the stator housing disposed above the returnway;

FIG. 7 is an isometric view of a conveyor with a drive system as in FIG. 3;

FIG. 8a is an isometric view of a drive system as in FIG. 2, but with sprockets, instead of a drum, housing the rotor;

FIG. 8b is an isometric view of a drive system as in FIG. 8a with permanent magnets in the rotor;

FIG. 8c is an isometric view of a drive system as in FIG. 8b in which the permanent magnets are arranged in Halbach arrays;

FIG. 9a is an isometric view of a sprocket-drive system as in FIG. 8a in which the rotor and stator are axially spaced from the drive sprockets;

FIG. 9b is an isometric view of a sprocket-driven system as in FIG. 9a with a stator completely encircling the rotor;

FIG. 9c is an isometric view of a sprocket-driven system as in FIG. 9a in which the rotor is a conductive disc; FIG. 9d is an isometric view of a sprocket-driven system as in FIG. 9a in which the rotor is a conductive cylinder driven by a two-sided stator;

FIG. 9e is an isometric view of the stator end of the sprocket-driven system of FIG. 9b with the rotor housing removed from the housing for cleaning; and

FIG. 9f is an isometric view of a sprocket-driven system as in FIG. 9c with a conductive-disc rotor and in which a one-sided stator is housed in a minimal housing.

DETAILED DESCRIPTION

A curved linear-induction stator usable in a belt-conveyor drive embodying features of the invention is shown in FIG. 1a. The stator 10 has a core 12 which may be made up of a solid metal piece or metal laminations. Poles 14 extend radially from the core to outer pole faces 16 that define the arc of a circle. Coils 18 wrapped around the poles 14 form electromagnets that are energized by an alternating current to produce a magnetic flux wave through the pole faces 16. The magnetic flux wave travels from pole to pole in one direction or the other. (The coil on only one of the poles is shown in FIG. 1a for clarity.)

Unlike the stators of most motors, the stator 10 in FIG. 1a does not make a complete 360° circle. Instead, it extends only over an arc of about 90°. In fact, the stator is more like a curved linear-induction stator than a conventional motor stator.

FIG. 1b shows the stator 10 of FIG. 1a associated with a rotor 20 consisting of a plurality of rotor bars 22 embedded in the interior of a drive element, such as a drum 24, at regularly spaced circumferential intervals. The rotor bars 22 are separated from the stator pole faces 16 by a gap 26 that extends partway around the rotor. The magnetic flux from the stator poles crosses the gap and induces currents in the electrically conductive rotor bars that produce a magnetic field that interacts with the stator field. The resultant force causes the motor to rotate and chase the stator's traveling magnetic field. The drum 24 has a smooth cylindrical outer peripheral surface 28.

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Axial slots **30** in the outer surface at a regular pitch form drive faces **32** that can drive drive-receiving surfaces on a conveyor belt. Or the outer drive surface can be smooth, uninterrupted by slots, for frictionally engaging and driving a tensioned flat belt.

In FIG. **1c** the rotor bars **22**, which are preferably made of aluminum or another electrically conductive material, are backed by torque reaction bars **34**, which may be made of a ferrous material, such as steel, to increase the flux density and the drive force. (As used throughout the description and claims, the terms “conductive” and “nonconductive” refer to electrical conductivity.) As shown in FIG. **1d**, the rotor is sealed within a rotor housing **36** formed by the peripheral drive surface **28** and end caps **38** at each end of the housing. The rotor housing is mounted on a drive shaft **40** extending outward from the end caps. The rotor and the peripheral drive surface are coaxial with each other and with the axis **42** of the drive shaft. The peripheral drive surface is made of a non-magnetic and nonconductive material, such as plastic, so as not to interfere with the traveling magnetic field or to have currents induced in the drive surface.

FIG. **2** shows a belt drive with a rotor sealed within a rotor housing **36** as in FIG. **1d**. The stator is sealed within a non-magnetic and nonconductive stator housing **44**. The stator housing has generally smooth outer surfaces that are easy to clean. A conveyor belt **46** has drive faces **48** along one side of regularly spaced teeth **50** formed on the inner side of the belt. The teeth are received in slots **52** in the peripheral drive surface **28** of the drum **36**. The drive faces **32** bounding the slots engage the drive faces **48** to advance the belt in the direction of belt travel **54**. The conveyor belt **46** passes through the gap **26** between the stator housing **44** and the rotor housing **36**. The stator housing **44** presents a concave bearing surface **47** against the conveyor belt to ensure that a drive face **48** of the belt is engaged by a drive face **32** of the drum **36** at a position just ahead of the exit point **56** of the belt from the drum. In this way, the stator housing also serves as a position limiter for a low-tension, positively driven conveyor belt.

FIG. **3** shows a stator housing **58** mounted behind the rotor drum **36**. In this configuration, unlike that of FIG. **2**, the belt **46** does not pass through the gap **26**. For this reason, the gap can be narrower, which improves the coupling of magnetic flux from the stator to the rotor. Furthermore, the stator housing **58** could be formed as an extension of the conveyor carryway. The stator housings **44**, **58** in FIGS. **2** and **3** each have arms **60**, **61** that attach to the drive shaft **40** to maintain a fixed gap width between rotor and stator. Because the stator housing **58** in FIG. **3** does not contact the belt **46**, its concave face **62** cannot serve as a position limiter. A modified version of the stator housing in FIG. **3** is shown in FIG. **4** with a position limiter **64** attached to distal ends of the arms **61** of the stator housing **58**. The concave inner surface **66** of the position limiter bears against the belt **46** and maintains the belt tooth **50** engaged with the drive face **32** of the drum **36** just ahead of the exit point **56** of the belt from the drum. The position limiter **64** is connected to the arm **61** by legs **68**.

FIGS. **5** and **6** show conveyor belts **46** driven by a drive unit in the returnway, rather than at an end of the carryway as in FIGS. **2-4**. In FIG. **5** the stator housing **70** is mounted below the drum **36** with the belt passing through the stator-rotor gap **26**. In FIG. **6** the stator housing **70'** is mounted above the drum **36**, and the belt **46** does not advance through the narrower gap **26'**. The stator housing **70'** can be integral to the carryway. Snubber rollers **72** before the entrance and after the exit to the drum increase the circumferential extent of belt wrap around the drum.

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FIG. **7** shows a complete conveyor system, in which a stator housing **58** as in FIG. **3** is mounted at an end of the carryway. A motor controller **74** sends motor control signals over signal lines **76** to the stator in the housing **58** to control the magnetic flux wave, the rotation of the rotor and the drum **36**, and the belt speed and direction. The motor controller **74'** could alternatively be mounted within the stator housing **58**, as shown in FIG. **3**, requiring only the connection of ac line power. The motor controller could be operated and monitored remotely via a wireless RF link **75** or other remote control means. This would further improve the hygienic qualities of the conveyor.

Instead of using a drum as the driving element and rotor housing, the electromagnetic drives in FIGS. **8a-8c** use narrower sprocket wheels to house the rotors. In FIG. **8a** the rotor comprises a series of electrically conductive plates **78** embedded in nonmagnetic and nonconductive sprockets **80** mounted on a drive shaft **82**. The outer peripheral surfaces **84** of the sprockets engage and drive the conveyor belt **46**. Like the conductive rotor bars in FIG. **1c**, the conductive plates **78** can be backed by steel plates to reduce reluctance in the magnetic circuit between the stator and rotor. In the rotor configuration of FIG. **8a**, the electromagnetic drive, like the drives in FIGS. **1b** and **1c**, operates as an ac induction motor.

The sprockets **86** in FIG. **8b** contain permanent magnets **88** alternating circumferentially in polarity between outward north poles **N** and south poles **S**. In the sprockets **90** in FIG. **8c**, the magnets are arranged as Halbach arrays **92** of alternating polarity to concentrate the magnetic flux in the direction of the stator poles. The permanent magnet rotors of FIGS. **8b** and **8c** and the stators can be operated as permanent-magnet ac motors or as brushless dc motors, as could drum versions that contain permanent magnets in the rotors.

In FIG. **9a** the rotor is sealed in a rotor housing **94** in the form of a wheel axially remote from standard sprockets **96** mounted on a drive shaft **98**. The sprockets **96** have peripheral drive surfaces that engage the conveyor belt. The stator is sealed in a stator housing **100** that extends partway around the circumference of the embedded rotor. In FIG. **9b** the stator in a stator housing **102** completely encircles the rotor wheel **94** to form a conventional motor, but with the rotor and stator sealed in separate housings. In both these examples the rotor could include electrically conductive plates like those in the sprockets of FIG. **8a** or permanent magnets like those in FIGS. **8b** and **8c**. The motor formed by the rotor and stator has a single bearing **103** and requires no shaft coupler or reduction gear. And, as shown in FIG. **9e**, the rotor housing **94** can be slid along the drive shaft **98** away from the stator housing **102** for easy cleaning of both.

In FIG. **9c** the electromagnetic drive is axially remote from the drive elements as in FIGS. **9a** and **9b**, but the rotor is a sealed conductive disc **104** mounted on the drive shaft **98**. The stator is shown as a double-sided stator sealed in a stator housing **106** that extends partway around the periphery of the disc. The double-sided stator improves the coupling of magnetic flux to the disc rotor. But a single-sided stator could be used to rotate the disc **104**, as shown in FIG. **9f**, in which a minimal stator housing **107** is used for easy cleaning.

In FIG. **9d** a rotor drum **108** has an extension **110** that extends axially outward of its peripheral drive surface **112**. A conductive cylinder in the extension serves as a rotor that is rotated by the magnetic flux wave produced by a two-sided stator sealed in a stator housing **114** that extends partway around the rotor. A one-sided rotor could be used as well.

Although the invention has been described with reference to a few exemplary versions, other versions are possible. For example, the drive systems shown with sprockets could be

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used with drums, and vice versa. As another example, the rotor need not be mounted on the drive shaft and can be coupled to the drive shaft other than through a direct connection. For example, the rotor can be coupled to the drive shaft via a reduction gear, a sprocket-chain system, or a belt-pulley system. And, although all the drive systems described in detail have constant-width stator-rotor gaps, the gap width does not have to be constant. For example, a curved rotor could be used with a linear stator tangent to the rotor or with a curved liner stator having a much greater radius of curvature than the rotor and a diverging air gap. So, as these examples suggest, the claims are not meant to be limited to the versions described in detail.

What is claimed is:

1. A drive for a conveyor belt, comprising:
 - a drive element rotatable about an axis of rotation and having a rotor and a peripheral drive surface adapted to engage a conveyor belt;
 - a stator separated from the rotor across a gap extending partway around the rotor and receiving the conveyor belt between the drive element and the stator;
 - wherein the stator produces a traveling magnetic flux wave across the gap that interacts with the rotor to cause the rotor to rotate the drive element and drive the conveyor belt engaged by the peripheral drive surface.
2. A drive as in claim 1 wherein the rotor is enclosed within the drive element.
3. A drive as in claim 1 wherein the drive element is a drive drum.
4. A drive as in claim 1 wherein the rotor includes circumferentially spaced electrically conductive bars extending axially along the drive element interior to the peripheral drive surface.
5. A drive as in claim 1 wherein the peripheral drive surface is smooth.
6. A drive as in claim 1 wherein the peripheral drive surface has drive faces circumferentially spaced at a regular pitch.
7. A drive as in claim 1 wherein the peripheral drive surface is nonmagnetic and nonconductive.
8. A drive as in claim 1 wherein the rotor includes a plurality of circumferentially spaced magnets.

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9. A drive as in claim 1 wherein the rotor is an electrically conductive aluminum cylinder interior to the peripheral drive surface.

10. A drive as in claim 1 wherein the stator includes a plurality of circumferentially spaced poles having outer pole faces arranged along an arc of a circle.

11. A drive as in claim 1 further comprising a motor controller sending signals to the stator to control the traveling magnetic flux wave and the rotation of the rotor.

12. A drive for a conveyor belt, comprising:

- a drive element rotatable about an axis of rotation and having a rotor and a peripheral drive surface including drive faces circumferentially spaced at a regular pitch for positively engaging drive-receiving surfaces on a conveyor belt;
- a stator separated from the rotor across a gap extending partway around the rotor and producing a traveling magnetic flux wave across the gap that interacts with the rotor to cause the rotor to rotate the drive element and drive the conveyor belt engaged by the drive faces on the peripheral drive surface.

13. A drive as in claim 12 wherein the rotor is enclosed within the drive element.

14. A drive as in claim 12 wherein the drive element is a drive drum.

15. A drive as in claim 12 wherein the rotor includes circumferentially spaced electrically conductive bars extending axially along the drive element interior to the peripheral drive surface.

16. A drive as in claim 12 wherein the peripheral drive surface is nonmagnetic and nonconductive.

17. A drive as in claim 12 wherein the rotor includes a plurality of circumferentially spaced magnets.

18. A drive as in claim 12 wherein the rotor is an electrically conductive aluminum cylinder interior to the peripheral drive surface.

19. A drive as in claim 12 wherein the stator includes a plurality of circumferentially spaced poles having outer pole faces arranged along an arc of a circle.

20. A drive as in claim 12 further comprising a motor controller sending signals to the stator to control the traveling magnetic flux wave and the rotation of the rotor.

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